NPS-55Bd76081

NAVAL POSTGRADUATE SCHOOL

Monterey, California

MINIFAST - AN INTERACTIVE MODEL OF THE NAVY'S ENLISTED PERSONNEL SYSTEM

by

Richard W. Butterworth

August 1976

Approved for public release: distribution unlimited.

Prepared for:

Navy Personnel Research and Development Center
San Diego, CA 92152

f Naval Personnel
on, DC 20370

NAVAL POSTGRADUATE SCHOOL
Monterey, CA. 93940

Rear Admiral Isham Linder
Superintendent

Jack R. Borsting
Provost

The research being reported on here was supported by the Naval Personnel Research and Development Center, San Diego, California, the Bureau of Navy Personnel, Washington, D.C., and the Office of Naval Research through a grant to the University of California, Berkeley, California.

This report was prepared by:

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS-55Bd76081	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Minifast: An Interactive Model of the Navy's Enlisted Personnel System		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard W. Butterworth		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93940 Code 55Bd		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N6822176WR60086
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE August 1976 13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Navy Personnel Research and Development Center San Diego, CA 92152		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Minifast, Personnel, Interactive Model

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the MINIFAST model of the Navy's enlisted personnel system. The assumptions made and formulas used in computations are presented in detail, along with a general view of the modelling approach. The model, beginning with the selection of a subject rating, calculates an estimate of the yearly gains and losses of personnel, the promotions within, and the new recruits to the rating. A policy affecting the personnel

SEE NEXT PAGE

system can be quickly evaluated for its effect on overages and shortages of personnel, its effect on the advancement system, and the need for new personnel, for multiple years in the future. Thus MINIFAST is an interactive planning model for rapid policy evaluation.

MINIFAST - AN INTERACTIVE MODEL OF THE NAVY'S ENLISTED PERSONNEL SYSTEM

ABSTRACT

This report documents the MINIFAST model of the Navy's enlisted personnel system. The assumptions made and formulas used in computations are presented in detail, along with a general view of the modelling approach. The model, beginning with the selection of a subject rating, calculates an estimate of the yearly gains and losses of personnel, the promotions within, and the new recruits to the rating. A policy affecting the personnel system can be quickly evaluated for its effect on overages and shortages of personnel, its effect on the advancement system, and the need for new personnel, for multiple years in the future. Thus MINIFAST is an interactive planning model for rapid policy evaluation.

RICHARD W. BUTTERWORTH

Operations Research Department

Naval Postgraduate School

Monterey, California 93940

1. INTRODUCTION

1.1 The Personnel System

For the purposes of this report, we will define the Navy's personnel system to be the set of enlisted personnel in the Navy along with the rules and decisions which govern their entry to, advancement in rank, and exit from the Navy. Other considerations such as duty location, duty type, change of station, training, etc., are not explicity accounted for by our model and consequently will not be discussed. We will be concerned primarily with how the personnel system operates, on an aggregate level, described by the pay grade (PG), rating (job skill) and length of service (LOS) of personnel.

A force structure matrix is a categorization of personnel by LOS and PG, so e.g., the (i,j) entry is the number of personnel with LOS=i and PG = j. Force structure matrices are used to represent personnel inventories, personnel losses, e.g., attrition or retirement, personnel gains, e.g., prior service reenlistment, and other variables in describing the personnel system. Individuals are not considered as entities of our model, except to the extent that they are 'counted' in the various force structure matrices used.

1.2 Flow Models and MINIFAST

MINIFAST is a flow model meaning a model which calculates what the personnel system will do for some given policy scenario under a fixed set of mathematical assumptions. The general chain

of events, or flow of personnel begins with a statement of the current inventory in a force structure matrix. External losses and gains to the force are estimated and accounted for, allowing the user to input the effects of his scenario on these variables. The number of advancements in pay grade, internal movements, are calculated based on the authorizations for personnel and other variables, all of which the user can control. Finally, a number of recruits to bring into the force may be computed or prescribed by the user. The model's time step is one year (12 months), and the user can continue the model as far into the future as desired, in one-year steps.

The intended purpose of MINIFAST is to calculate the effects on the personnel system of multi-year authorizations and changes in or implementation of policies which affect in a quantified way losses or gains to the force, the availability of personnel for promotion or new recruits. Some of the effects quantified are the resulting force structure matrix of inventory on board in future time periods (including e.g., statistics such as average LOS, career ratios, top six ratios,... etc.) losses and gains in future periods, promotions required and force structure matrices of promoted personnel. Since the personnel system cannot always respond to all requirements asked of it, the model reveals potential shortages and excesses of personnel, distortions of the advancement system beyond its normal limits of flexibility, ... etc. Being an interactive model, the dialogue necessary to define a scenario is kept to a minimum so that the user is virtually never delayed. Thus MINIFAST is intended for use in situations

where many policies need rapid evaluation, sorting out those which justify more intensive analysis. For this reason, ratings are treated separately, not jointly, to preserve the fast reaction capability. (See Section 2 for ways in which some interrating effects are simulated.) The user specifies a rating to address from a data base containing all possible ratings, one of which is the pseudo-rating 'All Navy'. As such, MINIFAST is a multi-year planning model of the personnel system, and is not intended for such actions as the assignment, detailing, re-enlistment, promotion ...etc. of individuals.

1.3 MINIFAST and Other Models

MINIFAST is very similar to FAST in problem formulation. FAST is a non-interactive model of the personnel system, developed at NPRDC, San Diego, and described in [1]. The FAST model has become, in recent years, one of the primary computer models for detailed planning and analysis used by BUPERS for the enlisted force. Its output is used as input to other models and is, in general, accepted as a very good tool for detailed evaluation. One drawback to its use in quick reaction drills has been, however, the sometimes tedious set-up of input files and long turn-around times required due to its high level of detail. MINIFAST was specifically designed to have as nearly as possible, the same problem formulation and mathematical assumptions, while sacrificing the joint rating capability of FAST, allowing the interactive approach. This has been a successful endeavor, and, indeed, some fresh insights gained from the development of MINIFAST have resulted in changes

to the FAST model, making the differences between their formulations minor.

The academic literature is replete with personnel models (see [2]) ; however, we see no way to classify MINIFAST as one of them. That is, MINIFAST is not a goal programming, nor a queueing, nor a linear programming model. As explained in Section 2, various mathematical techniques enter in, including smoothing, regression, linear equation solving,...etc., however, in a limited way.

The model duplicates or simulates (in a non-statistical way) the behavior of the personnel system, taking as input those quantities which the decision maker directly controls or influences such as authorizations, retirements, contract losses,...etc., and calculates their impact throughout the system in terms of the inventory force structure, advancements,...etc. Any 'optimization' of the system is accomplished by the user, testing his proposed policies by simulating their effects, readjusting his expectations of the feasible and avoiding whenever possible costly errors. The model's user, someone conversant with the personnel system, becomes the optimizer.

2. THE MINIFAST MODEL

2.1 Problem Formulation

In this section we will be discussing the general formulation of our model for the personnel system, and the precise mathematical statements used in MINIFAST. For instructions on hands-on use of the model, one is referred to the MINIFAST USERS GUIDE, available as a separate document([4]).

As an overview of the model, this subsection deals with our formulation of the personnel system, defining the various terms used later.

Personnel are categorized, in MINIFAST, by their rating which is a job skill category of which there are about 95, their rate, i.e., pay grade, which is expressed as E1, E2,..., E9 from lowest to highest, and their length of service, or LOS, measured from date of entry to the present. The model is pertinent to a single rating which can be any one in the data base This includes (currently) the 73 general ratings where service ratings are recombined with their parent general rating and 'All Navy'. Personnel in pay grade E1, E2, and E3 are, generally, unrated, i.e., do not have a rating and are in a "recruit" classification. These personnel have not yet received experience or training prerequisite for a rating and constitute the pool of available personnel from which entry to one of the ratings takes place. Since their advancement from E1 to E2 to E3 is decentralized and mostly automatic, we, by convention, include E1 and E2 with E3. For modelling purposes then, personnel

in E1 and E2 are not distinguished from those in E3, and the set of feasible pay grades becomes E3, E4, E5, E6, E7, E8, and E9. This same convention is used in FAST. Finally, LOS, is discretized by years with LOS cell m referring to those personnel with between m-1 and m years service.

The primary statement of personnel needs in the future are made with requirements and authorizations. Requirements are determined by examining billet records, i.e., statements of job positions, and are aggregated to the level of ratings and pay grades for budget review. The budget process results in authorizations which are funded requirements by rating and pay grade. The personnel system is then geared to supply persons in these numbers. Individual ratings have no meaningful requirements or authorizations for E3; however, for 'All Navy' a total end strength is authorized, and hence there is an implicit E3 authorization.

Losses and gains from the Navy account for all yearly changes to the force structure, except promotions and new recruits. Taking account of the losses and gains in a beginning inventory results in a net inventory of personnel, assumed to be essentially those available to the promotion process, but not all of whom are resources for advancement. The net inventory never really exists at any point in time, but does estimate the supply of personnel prior to advancement.

The promotion process is vacancy driven. Starting with E9 authorizations less the net E9 inventory for vacancies at E9, promotions from E8 are made to fill these vacancies, subject to

the availability of E8 personnel with sufficient time in service and scores to qualify. These promotions as well as external losses create vacancies at E8 which are then filled from E7, subject to personnel availability in E7. Finally, vacancies at E4 are assumed filled from E3, corresponding to entry into the rating. When vacancies in some pay grade cannot be filled entirely, the shortfall is carried down to the vacancies at the next lower pay grade. This practice is consistent with assignment policies which permit grade substitution when necessary to fill billets.

Recruits are brought into the Navy with the usual intention of filling the supply of personnel up to the total end strength authorized by Congress. Their entry into individual ratings is influenced by various factors, such as the capacity of schools, aptitude and interest of the personnel,...etc.

In the following subsections, we will discuss in greater detail the mathematical aspects of our model.

2.2. Authorizations and the Beginning Inventory

In what follows, we will present an annotated terminal session with MINIFAST. It begins as a display of future authorizations for five consecutive time periods, by pay grade, for the chosen rating, as illustrated by Figure 1. These numbers can be modified for testing changes in the authorization plans, or any conjectured policy change which would alter future authorizations.

```
SAMPLE OUTPUT
RATING     0 Y76      ALL NAVY
RUN ON   7/02/76  RELEASE 4   1 MAY 76


AUTH STRENGTH       E3       E4       E5       E6       E7       E8       E9
     PERIOD  1 185159   91487   81057   65755   31009    8313    3596
□:
      OK
     PERIOD  2 182135   96801   85521   69686   32203    8831    3791
□:
      OK
     PERIOD  3 179894   97656   86260   70324   32472    8934    3843
□:
      OK
     PERIOD  4 176896   98094   86668   70662   32620    9000    3878
□:
      OK
     PERIOD  5 176382   99923   88276   72003   33195    9194    3968
□:
      OK
```

BEGINNING FORCE, PERIOD 1

	E3	E4	E5	E6	E7	E8	E9	E4-E9	TOTA
INV	183458	93324	79388	65990	31733	8211	3556	282202	46566
MEAN LOS	1.63	3.40	7.19	13.63	18.02	20.23	22.85	9.24	6.2
CR FORCE	8442	21220	66098	65910	31728	8210	3554	196720	20516

TOP SIX RATIO 60.60 PERCENT

FIGURE 1

Some statistics on the beginning inventory are displayed, namely average LOS, career force, and top six ratio. Defining

I = Force Structure Matrix of beginning inventory, so

I(ij) = Number of personnel with length of service = i, pay grade = j, i = 1, 2,...31, j = 1,...7 (for E3,... E9, respectively) then the average LOS shown for any given pay grade j is

$$\text{Average LOS in PG } j = \sum_{i=1}^{31} (i-0.5)I(i,j) \div \sum_{i=1}^{31} I(i,j).$$

The career force are those personnel with four or more years in the service, or

$$\text{Career force in PG } j = \sum_{i=5}^{31} I(i,j).$$

The top six ratio is the petty officer to total force ratio, or

$$\text{Top Six Ratio} = \sum_{j=2}^{7} \sum_{i=1}^{31} I(i,j) \div \sum_{j=1}^{7} \sum_{i=1}^{31} I(i,j) .$$

These statistics are particularly relevant indicators for personnel managers monitoring the system, as they relate to the cost and experience level of the force.

2.3 Loss and Gain Prediction and Modification.

Losses and gains are predicted next, based on the beginning inventory. Letting

L = any specific loss or gain prediction matrix, so

$L(i,j)$ = Number of losses from beginning inventory with LOS = i, pay grade = j,

then

$$L(i,j) = \alpha(i,j) \cdot I(i,j)$$

where α = fractional rate derived historically.

The data base has rate matrics α for every type of loss and gain used, for every rating. These data are derived by a smoothing technique for the FAST model, and are taken directly from that data base. The different variables predicted form a partition of total losses and gains, and are as follows:

Losses:

Attrition
Contract Loss
Demotions Out
Expiration of Active Duty Obligated Service (EAOS)
Laterals Out
Retirement

Gains

Prior Servie Reenlistment (CS/BS)
Demotions In
Laterals In
Misc. Gains
Retention
Direct Procurement Petty Officers (DPPO)
Reserves

Some discussion of these variables is helpful at this point. Attrition is losses from the service for reasons other than contract expiration and retirement, e.g., for death, dishonorable discharges, health or hardship discharges, failure to adjust to military life, and for the convenience of the government generally. Contract losses, EAOS, and retention are discussed below. Demotions out and demotions in account for the internal changes due to demotions. Both are necessary since demotions can be and often are across several pay grades. Laterals out and in represent changes external to the rating, however, internal to the Navy. This is an example of an inter-rating effect which can be simulated, even as ratings are treated individually. Retirement is simply those personnel with over 18 years service who retire. Personnel leaving the Navy and returning in a short period of time are continuous

service gains, and can generally return to the position they vacated. Broken service gains are those allowed to return after an extended departure, and prior service reenlistment covers both. The prediction of DPPO gains is nominally zero, but can be given a value as explained below. Reserve input while being predicted can be given specific values instead, if known.

The largest magnitude external change is always contract loss, those personnel whose expired contract is not renewed. The larger set, EAOS, are those who, during the year, will have their contract expire. The complement of contract losses are called retention, so by definition,

EAOS = Contract Loss + Retention.

Any of the 13 variables listed above can be displayed or modified at the user's request. See Figure 2,A,B for an example of attrition being displayed and then updated. The purpose of this is to evaluate policies which are presumed to have some effect on the variables which cannot be historically predicted. For example, a specific bonus policy for a rating, aimed at decreasing contract losses from E4, can be tested by simulating the decrease. As another example, lateral input or exit from a rating could be postulated and entered as a modification of the usual lateral changes. The amount of change necessary to solve a specific problem at hand can be addressed in this manner as well.

```
LOSSES AND GAINS IN PERIOD 1
D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

DISPLAY

WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      ATTR
ATTRITION NOW HAS VALUES :

    PAY GRADES :
       3        4        5        6        7        8        9
   26892     4872     2694     1366      465      127       58

    LOS :
       1        2        3        4        5        6        7        8
   12047    10609     5260     1978      880     1188     1125      727

       9       10       11       12       13       14       15       16
     379      376      256      206      160      149      127      112

      17       18       19       20       21       22       23       24
     103       75       76      199      155       73       44       39

      25       26       27       28       29       30       31       32
      18       13       10       13       12       24       41    36474


D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

UPDATE
WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      ATTR,¯3
ATTRITION NOW HAS VALUES :

    PAY GRADES :
       3
   26892
INPUT  1 NEW VALUES FOR ATTRITION
⎕:
      35000
OVERRIDE ACCEPTED
D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED
```

FIGURE 2-A ATTRITION MODIFICATION

```
LOSSES AND GAINS IN PERIOD 1
D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

DISPLAY

WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      ATTR
ATTRITION NOW HAS VALUES :

    PAY GRADES :
         3         4         5         6         7         8         9
     35000      4872      2694      1366       465       127        58

    LOS :
         1         2         3         4         5         6         7         8
     15360     13541      6440      2269       973      1267      1238       780

         9        10        11        12        13        14        15        16
       394       389       264       213       162       151       129       114

        17        18        19        20        21        22        23        24
       103        76        76       199       156        73        44        39

        25        26        27        28        29        30        31        32
        18        13        10        13        12        24        41     44582


D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

FORECAST
WHICH VARIABLE ?
⎕:
      ATTR
OVERRIDE ACCEPTED
D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED
```

FIGURE 2-B MODIFIED ATTRITION

When a user wishes to modify a prediction for some reason. it is infeasible to ask him to modify the predicted force structure matrix cell by cell, so the following method is used. (See Figure 2 for an example) New values can be given to any subset of the pay grade totals, LOS totals, or grand total, and are applied according to the following algorithm. Let

L = matrix prediction of the variable prior to modification, then

$$L'(i,j) = L(i,j) \cdot B_j \div \sum_{k=1}^{31} L(k,j) \quad i=1,\ldots,31, \quad j=1,\ldots,7$$

where B_j = the modified j^{th} pay grade total entered or the existing total if no new value was entered.

$$L''(i,j) = L'(i,j) \cdot C_i \div \sum_{k=1}^{7} L'(i,k) \quad i=1,\ldots,31; \; j=1,\ldots,7$$

where C_i = the modified i^{th} LOS total entered, or the existing (from L') total if no new value given.

$$L'''(i,j) = L''(i,j) \cdot D \div \sum_{k=1}^{7} \sum_{\ell=1}^{31} L''(\ell,k) \quad i=1,\ldots,31, \; j=1,\ldots,7$$

where D = the modified grand total entered, or the existing (from L'') grand total if no new value was given.

L''' = final modified matrix for the variable.

Note that this method of up-dating or modifying predicitions attempts to preserve as nearly as possible the linearity between predictions and inventory, and the relative proportions in the likelihood matrix α. If pay grade totals but no other totals are modified, the new variable has these totals. If, however, even one LOS total or the grand total is modified also, the new variable will not have exactly the modified pay grade totals entered. This method discourages a user from distorting the prediction matrix too severely.

When any one of the three variables: contract losses, EAOS, or retention are modified, the equation above is violated. The model then allows the user to automatically recompute the two remaining variables, making the equation valid again. Figure 3 gives the example in which EAOS is modified in response to an early-out policy or perhaps an improvement in the EAOS prediction from outside data sources. Then a recomputation of contract loss automatically modifies it as if it were predicted in proportion to the new EAOS. Specifically,

$$C = E \cdot A \div B$$

where C = Recomputed Contract Loss Matrix

E = Modified EAOS Matrix

A = Prediction matrix (α) for contract loss

B = Prediction matrix (α) for EAOS

and the multiplication and division indicated is performed on a cell by cell basis. Retention (R) would also be recomputed by the equation

$$R = E - C.$$

```
DISPLAY

WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      CLOSS,32

CONTRACT LOSS NOW HAS VALUES :

    LOS :
      32
   58674


D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

UPDATE

WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      EAOS,32

EXPIR ACT OBL SV NOW HAS VALUES :

    LOS :
      32
  113820


INPUT  1 NEW VALUES FOR EXPIR ACT OBL SV
⎕:
      120000

EAOS EQUATION TILTS IN ELEMENTS
¯3  ¯4  ¯5  ¯6  ¯7  ¯8  ¯9  1  2  3  4  5  6  7  8  9  10
      11  12  13  14  15  16  17  18  19  20  21  22  23  24
      25  26  27  28  30  31  32
A=ABORT, B=BALANCE EAOS EQ, C=CARRY ON

BALANCE
OVERRIDE ACCEPTED
D=DISPLAY, U=UPDATE, F=FORECAST, P=PROCEED

DISPLAY
WHICH VARIABLE, WHICH ELEMENTS ?
⎕:
      CLOSS,32

CONTRACT LOSS NOW HAS VALUES :

    LOS :
      32
   61860
```

FIGURE 3 EAOS MODIFICATION

If instead retention itself were modified, then a recomputation of contract losses would be

$$C = E - R$$

and EAOS (E) would remain unchanged. Since so many of the policies considered affect contract losses in some way, the above procedures are indispensable to real applications. When all losses and gains are used to calculate the net inventory, only Contract Loss is included, i.e., EAOS and Rentention are ignored.

To guard against errors on input or possible abuses, every modification is examined for its feasibility. Any change which would produce a negative cell value in the net inventory matrix is disallowed. Any increase in contract loss or retention which exceeds EAOS in some cell is also disallowed by the model.

2.4 Promotions

As soon as a set of losses and gains have been derived as explained above, the model proceeds to the promotion section. First, promotion resources for the top six petty officer ranks are estimated. This is an estimate of the number of personnel who will have passed the advancement test for the next higher rate, and who have sufficient time in service to qualify for promotion, sometime during the year in question. Estimates are made by pay grade only, according to the formulas:

$$AR(j) = B(j) \sum_{i=a(j)}^{c(j)} NET(i, j-1)$$

where

AR(j) = Advancement Resources for promotion to PG j

$j=2,3,\ldots,7$ (E4,E5,...,E9)

B(j) = historically derived fractional rate

Net = Net Force Structure Matrix

a(j)= youngest LOS cell allowed for promotion to j

c(j)= oldest LOS cell allowed for promotion to j

Each rating's data base contains the data specific to that rating, including the B's, a's and c's. The Net matrix is calculated as the beginning inventory plus gains minus losses. The above values of AR are displayed to the user, and can be modified to reflect up-dated estimates or policy changes which would affect them as shown in Figure 4. The model automatically constrains any new value of AR to be below the test taker eligible (TTE) population, defined by

$$TTE(j) = \sum_{i=a(j)}^{c(j)} NET(i,j-1)$$

```
        PROMOTIONS IN PERIOD 1
                          E4      E5      E6      E7      E8      E9
ADV RESOURCES          61366   46478   50421   19175   11993    4042
⎕:
      62000 45000
ADV RESOURCES          62000   45000   50421   19175   11993    4042
⎕:
      OK
RECRUIT ADV             6527      31      11       2       1
⎕:
      OK
APPORTIONMENT         100.00  100.00  100.00  100.00  100.00  100.00
⎕:
      OK
```

FIGURE 4 ADVANCEMENT PREPARATION

The recruit advancements are those personnel who enter the system without prior service and are advanced into the petty officer ranks in the same year. The number of such personnel is usually small and is determined by policy. The model will use last period's recruit advancements this period as well unless the user enters his own values interactively at this point. Note that last period's policy is in the beginning inventory matrix I;

$$RA(j) = I(1,j) \qquad j = 2,\ldots,7 \; (E4,\ldots,E9)$$

where $RA(j)$ = default recruit advancements into pay grade j

When authorizations are made for each rating, some ratings cannot use all their authorizations because of lack of sufficient resources for promotion, excessive losses, etc. When this occurs, other ratings which were authorized at a level below their stated requirements received extra authorizations, called apportioned authorizations, or simply apportionment. The determination of apportionment is an inter-rating matter and cannot be treated by MINIFAST. The model does, however, accept a value for apportionment in each of the top six pay grades. This apportionment is actually viewed as the new target population replacing authorizations and is expressed as a percentage of the authorizations. Its default value is 100% (essentially no apportioned authorization) in each pay grade and can be revised to any other value by the user. This is another example of inter-rating effects accounted for in the model.

When advancement resources, recruit advancements, and apportionment have been interactively agreed to or reset, the promotion

computations can begin. These result in a printed table which shows what the advancement system will do to meet its goals. Figure 5. is a sample of the output.

	E4	E5	E6	E7	E8	E9
AUTH STRENGTH	91487	81057	65755	31009	8313	3596
APPORTIONMENT	91487	81057	65755	31009	8313	3596
PROMOTIONS TO	45732	31842	13842	6504	2372	802
END STRENGTH	82389	81057	65756	31007	8309	3594
PERCENT WAIVER	25.00	6.96	5.74	2.30	2.68	9.79
MEAN LOS OF ADV	2.13	4.20	8.18	14.40	18.16	20.42
PERCENT AUTH	90	100	100	100	100	100

RE-ENTER ADVANCEMENT CYCLE ?
NO

FIGURE 5 ADVANCEMENT OUTPUT TABLE

The computed output begins with authorized strength and apportionment. The word apportionment is used two ways here; first as a percentage of authorizations, then as the actual number of billets.

The promotion algorithm is vacancy driven with promotions to E9 made first, followed by E8,...,E4. End strength is the population following promotion and should be equal to apportionment if the advancement system was able to supply all the needed personnel. The percent of personnel in the waiver zone relates to a DOD restriction on the fraction of personnel in each petty officer rank with less than the nominally required years of service which can restrict promotions to avoid violating set limits. This was in fact the case in Table 5, for E4, where the limit of 25% was constraining. End strength only reached 90% of authorized strength

in E4, despite the apparent availability of sufficient resources. The mean LOS of advancing personnel indicates the experience level, mean time in service, and generally the promotion opportunities for personnel.

A mathematical formulation of the promotion algorithm is given for one pay grade. In application, the algorithm is applied first to E9, then E8,..., lastly to E4. The vacancies (V) to fill are computed by

$$V = AP + CD - N - RA + PT'$$

where:

AP = Apportioned billets

CD = Carry down to this pay grade from above of unfilled vacancies (= 0 for E9).

N = Net inventory in this pay grade before any promotions are made.

RA = Recruit Advancements into this pay grade.

PT' = Promotions from this pay grade into the next higher (= 0 for E9).

If there were no constraints binding, promotions to this pay grade, PT, would simply be V. To understand the first contraint, we must first discuss waiver and promotion zones.

For each pay grade, there is a waiver zone and promotion zone. These are LOS zones of the form (a,b) = waiver zone, (b,c) = promotion zone. E.g, in E7, 8 - 9 years = waiver zone, 10 - 30 years the promotion zone. Certain policies maintain that

ideally all personnel in a pay grade should have their years of service in the promotion zone before being promoted; however, exceptions are made out of necessity for personnel who are in the waiver zone, within limits. The limit is a maximum on the fraction of personnel serving in their pay grade's waiver zone out of all personnel serving in that pay grade. In other words, the limit is not on advancees per se, but on the resulting population in the net inventory in these zones.

$$AR(W) = AR \frac{\sum_{i=a}^{b-1} NET(i,j-1)}{\sum_{i=a}^{c} NET(i,j-1)}$$

$$AR(P) = AR \frac{\sum_{i=b}^{c} NET(i,j-1)}{\sum_{i=a}^{c} NET(i,j-1)}$$

$$AR = AR(W) + AR(P)$$

where

AR(W) = Advancement Resources in Waiver Zone

AR(P) = Advancement Resources in Promotion Zone

j = assumed index of pay grade in question

Given this breakdown of resources, the number of promotions to the pay grade are found in the waiver zone and promotion zone by the following method. First we begin by computing:

$$PT(P) = MIN\left(\alpha \cdot MAX(V, \beta \cdot AR),\ AR(P)\right)$$

$$PT(W) = MIN\left((1-\alpha) \cdot MAX(V, \beta \cdot AR),\ AR(W)\right)$$

where $\alpha = AR(P) \div AR$

β = token advancement fraction (from data base)

Thus we attempt to fill all vacancies or token vacancies if these exceed actuals, but are constrained by advancement resources. If making the promotions PT(P), PT(W) would violate the waiver zone limit, namely if

$$\left(\sum_{i=a}^{b-1} ADV(i,j)\right) \div \left(\sum_{i=1}^{31} ADV(i,j)\right) \geq w_j$$

where w_j = waiver limit from data base,

ADV = Advanced Inventory, i.e., inventory <u>after</u> advancements

then PT(W) is reduced by an amount X and PT(P) increased by X until either the waiver limit is met or resources exhausted, i.e., PT(P) + X = AR(P). If the waiver limit is met first, calculation stops with these values. If resources are exhausted first, then PT(P) remains = AR(P), and AR(W) is reduced to zero, if necessary, until the waiver zone limit is met. Note that losses, say due to retirement, can force a pay grade to violate its waiver limit, even if no waiver zone promotions $\left(PT(W) = 0\right)$ are made. Also notice the recruit advancements are automatically 'counted' among the waiver zone personnel.

Next, the model estimates which LOS cells the advancees will come from. The current method assumes equal <u>likelihood</u> for advancement from all cells, and, hence, advances personnel in proportion

to their numbers in each LOS cell of the NET inventory at the pay grade below. Selection is constrained so as not to exceed the number present and the waiver and promotion zones are done separately. This method is currently under study, and an improved method which essentially provides a differential likelihood by LOS is nearly developed. A more detailed explanation of the current method seems, hence, unnecessary. See [3] for a preliminary study concerning this question.

Once promotions by LOS have been calculated, they are used to calculate the Advanced Inventory.

$$ADV(i,j) = NET(i,j) + A(i) - A'(i)$$

$$i = 1,\ldots,31$$

$$j = 2,\ldots,7 \quad (E4,\ldots,E9)$$

where ADV = Advanced Inventory

A = LOS vector of promotions to PG j

A = LOS vector of promotions from PG j

Notice that we will have

$$PT(W) = \sum_{i=a}^{b-1} A(i)$$

$$PT(P) = \sum_{i=b}^{c} A(i)$$

Finally, if there are unfilled or overfilled vacancies, the model "carries down" these vacancies to the next lower pay grade. The carry down, however, is based on authorizations, not approtionment, as the goal. This is because apportioned authorizations are not

intended to create a surfeit of personnel in the rating receiving the apportionment, but are added after normal promotions in the pay grade. Thus our equation for carry down from this pay grade to the next lowest, CD' is

$$CD' = V - PT + (AU - AP)$$

where

$PT = PT(P) + PT(W)$

$\quad = $ total promotions to the pay grade

$AU = $ authorizations for this pay grade

$AP = $ apportionment for this pay grade

As the algorithm begins the next lowest pay grade, the new carry down becomes $CD = CD'$ and the new promotions from becomes $PT' = PT$. Output options for the MINIFAST model can provide a detailed printout of the advancing and advanced inventories, and carry down, in addition to the information in Figure 5.

2.5 Recruit Input and End Strength

After the effects of the promotion process have been calculated as explained above, the recruits being brought into E3 are the only remaining change to the force structure to account for. In the real world situation, recruits in E3 are not identified with any specific rating, with a few exceptions called 'strikers'. The model does assume, however, an E3 population in the beginning inventory matrix. This is a 'phantom' inventory which conceptually represents the number of E3's in the Navy. Their value in the initial inventory is

established by the FAST model, and the same approach is used there. For the pseudo-rating 'All Navy', the E3 inventory is very real.

The MINIFAST model computes the number of recruits assumed to enter a rating's E3 population during the year. The value is derived by estimating the number of promotions to E4 expected next period, and the total number of E3's needed now to make just enough personnel available. The total number of recruits to bring aboard is then estimated after taking into account recruit losses during the year. The equations used are:

$$P_j = A_j - S_j \cdot \gamma_j + P_{j+1} - RA'_j \qquad j = 2, \ldots, 7$$

where

P_j = next period's estimated promotions to j ($P_8 = 0$)

A_j = next period's authorizations in j.

S_j = next period's beginning inventory in j.

γ_j = estimated continuation rate from beginning to NET inventory, in j, next period.

RA'_j = next periods recruit advancements into j.

Solving for P_2 gives the equation

$$P_2 = \sum_{j=2}^{7} (A_j - S_j \cdot \gamma_j - RA'_j).$$

This implies that the desired E3 end strength (ES) is

$$ES = P_2 \div \gamma_3$$

and the number of recruits in E3 remaining at period's end should be

$$RC = ES - S_1$$

so that the total number of E3 recruits to bring aboard before losses is

$$RC \div (1 - \alpha_1)$$

where $\alpha_1 = E_3$ recruit loss rate.

Actually, the grand total number of recruits to bring aboard also includes this period's recruit advancements, (RA_j) before losses at rate α_j, or

$$RC \div (1 - \alpha_1) + \sum_{j=2}^{7} RA_j \div (1 - \alpha_j)$$

This value for total recruits is prescriptive and can be overridden by the user with some other value. The minimum value accepted by the model, however, is that necessary to supply the recruit advancements, since they were previously committed to by the user.

The data fractions (α_j) representing the recruit loss rate reside in each rating's data base. They are defined to be the fraction of all recruits joining during the year who have left before the year's end. This represents essentially boot camp attrition and beginning school attrition. Due to the discretization of time into yearly segments by the model, this loss rate is defined in a slightly awkard way, and special attention to its estimation is necessary to avoid confusion.

The entry of reserves into the force is very similar to that of recruits, however formally reserves enter as a "gain", as described in an earlier section. To simulate the recruit-entry of reserves, one can interactively set the reserve gains to zero and enter them here as additional recruits. The difference in these methods is that as a gain, reserves can enter in LOS cells 1 to 31 and pay grade E3 - E9. As recruits, however, they can only enter in LOS cell o (meaning cell 1 of the next year) and pay grades E3, or E4 - E9 as a recruit advancement.

The recruit algorithm described thus far is for ratings. For All Navy, the rationale for recruits is slightly different. The Navy is authorized a total end strength in addition to the petty officer end strengths discussed above. In this case, the number of recruits necessary to meet this total end strength is calculated and used as a prescribed value. See Figure 6 for an example.

```
        RECRUIT PROJECTION IN PERIOD 1
TOTAL RECRUIT INPUT PROJECTED IS  83806
FROM WHICH ESTIMATED LOSSES ARE 12571
LEAVING NET RECRUITS (EXCLUDING RESERVES) OF   71235
AND A TOTAL END STRENGTH OF 466375


IS A RECRUIT TOTAL OF  83806 OK?
⎕:
      OK


        FINAL END STRENGTH, PERIOD 1
            E3      E4      E5      E6      E7      E8      E9   E4-E9   TOTAL
INV      194264   82389   81057   65756   31007    8309    3594  272112  466376
MEAN LOS   1.76    3.35    7.12   13.16   17.81   20.26   22.94    9.27    6.14
CR FORCE   9550   18609   62211   65383   31000    8307    3593  189103  198653
TOP SIX RATIO 58.35 PERCENT
```

FIGURE 6 RECRUIT PROJECTION AND FINAL END STRENGTH

The last step in arriving at the final force structure matrix is to age the advanced matrix by one LOS cell and put recruits into the first LOS row.

$$F(i,j) = ADV\ (i-1,\ j) \qquad i = 2,\ldots,31;\quad j = 1,\ldots,7$$

$$F(1,1) = RC$$

$$F(1,j) = RA_j \qquad j = 2,\ldots,7$$

where F = Final force structure matrix of inventory

The model displays statistics for this final inventory (Figure 6) just as done for the period's beginning inventory. If continued into the next planning period, the model simply replaces its beginning inventory by this final one and control resumes at the start again.

3. COMPUTER IMPLEMENTATION OF MINIFAST

The section gives some general information on the computer aspects of our model. For details of the hands on use of MINIFAST, see the MINIFAST USERS GUIDE.

3.1 Language and Host Computer Considerations

MINIFAST is written in the APL language which still enjoys a reasonable degree of commonality among the various APL interpreters and host computers. The major difference between the various APL implementations is their file storage and retrieval systems.

Currently, there are two distinct operating programs for MINIFAST. One uses the XM-6 release (earliest commercially available) in a CP/CMS environment at the Naval Postgraduate School's Computer Center. File functions use a binary (internal) storage format for economy.

The other version, and the one intended for production use, is stored on the Boeing Computer Service time-sharing CMS system. Its file organization uses the shared variable facility and stores data in internal format. This second program could be adapted to most APL implementations with SV features such as APLSV or VSAPL. The second program is, due to the host computer, substantially faster in execution than the first. Both versions require an active workspace size of about 88K.

3.2 Data Base Organization

The data base is organized along the rating dimension for each file. That is, each rating is supported by a file whose records are the data necessary to use MINIFAST for that rating. Each file is hence layed out identically with variable length records. This approach facilitates the addition and subtraction of ratings to the data base. Table 1 shows the record contents for a rating's file. The actual record format depends upon the file system being used.

3.3 Cost of Operation

The data base storage costs vary greatly with the number of ratings kept on-line. Since most ongoing studies with MINIFAST will only use several ratings, most can be stored off-line, on tape for example. They can be quickly brought on-line in several minutes when needed. A minimum storage cost for several ratings and the MINIFAST program is about $40.00 per month at prevailing commercial rates.

The marginal cost of making a projection with MINIFAST includes the sign-on time and CPU time charges. This varies with the number of changes to loss and gain predictions and other inputs made, as well as, terminal type and time of the day (prime time VS off hours). Under current commercial rates, the cost is a minimum of about $2.00 per year projected, up to $15 per year. These cost figures have been decreasing as improvements in the code are discovered, and continue to be subject to change.

REC. NO.	RECORD LENGTH* (BYTES)	APL SHAPE	APL TYPE	RECORD CONTENTS
1	80	80	CHAR	Rating Name
2	868	31 7	INTEGER	Beginning Inventory
3	140	3 7	INTEGER	Authorizations
4	26	26	CHAR	Blank - hold for expansion
5	48	6	REAL	Test Passer Rate
6	48	6	REAL	Apportionment Rate
7	24	6	INTEGER	Last Advancement Resources Used
8	26	26	CHAR	Blank - hold for expansion
9	56	7	REAL	Recruit Loss Rate
10	24	6	INTEGER	Last Recruit Advancements Used
11	120	6 5	INTEGER	Promotion, Waiver Zone/Limit, Token %
12	26	26	CHAR	Blank - hold for expansion
13	26	26	CHAR	Blank - hold for expansion
14	26	26	CHAR	Blank - hold fot expansion
15	868	31 7	INTEGER	Attrition Loss Rate-Parts Per Million
16	868	31 7	INTEGER	Contract Loss Rate-Parts Per Million
17	868	31 7	INTEGER	Demotions Out Rate-Parts Per Million
18	868	31 7	INTEGER	EAOS Rate-Parts Per Million
19	868	31 7	INTEGER	Laterals Out Rate-Parts Per Million
20	868	31 7	INTEGER	Retirement Rate-Parts Per Million
21	868	31 7	INTEGER	Any Additional Loss (Zero Now)
22	868	31 7	INTEGER	Any Additional Loss (Zero Now)
23	868	31 7	INTEGER	CS/BS, Reenlistment Rate-Parts Per Million
24	868	31 7	INTEGER	Demotions In Rate-Part Per Million
25	868	31 7	INTEGER	Laterals In Rate-Parts Per Million
26	868	31 7	INTEGER	Misc. Gain Rate-Parts Per Million
27	868	31 7	INTEGER	Retention Rate-Parts Per Million
28	868	31 7	INTEGER	DPPO Rate-Parts Per Million
29	868	31 7	INTEGER	Reserve Input Rate-Parts Per Million
30	868	31 7	INTEGER	Any Additional Gain (Zero Now)

* Actual record length may be up to 20 bytes longer, depending on the file system.

TABLE 1. DATA BASE FILE STRUCTURE

4. ACKNOWLEDGEMENTS

The conceptual framework for our model, as well as the wealth of data to support it, was generously supplied by Mr. Joe Silverman and Mr. Robert Boller, members of the NPRDC staff, San Diego. Out understanding of the personnel system was also enhanced by discussions with the BUPERS, PERS 2 staff. Test and development of the coding was carried out at the W. R. Church Computer Center, Naval Postgraduate School. This project was supported by the Naval Personnel Research and Development Center, San Diego, and the Office of Naval Research through a grant to the University of California, Berkeley, and by the Bureau of Naval Personnel, Washington, D. C.

REFERENCES

[1] Boller, Robert L., "Design of a Force Structure Model for the Simulation of Personnel Policy," presented at 33rd Military Operations Research Symposium, United States Military Academy, West Point, New York, June 25-27, 1974.

[2] Charnes, A., Cooper, W. W., Neihaus, R. J., "Studies in Manpower Planning," Office of Civilian Manpower Management July 1972.

[3] Milch, Paul R., "A Model for the Prediction of Advancements in the Navy Enlisted Force," Project Report for NPRDC, San Diego, 1 July 1976 (207 pp.)

[4] Butterworth, Richard W., "Minifast User's Guide", Naval Postgraduate School, Monterey, California, March 1976, 18 pages.

DISTRIBUTION LIST

	No. Copies
Dean of Research Administration Naval Postgraduate School Monterey, CA 93940	1
Naval Personnel Research and Development Center	
Attn: Mr. Robert Boller	1
Attn: Mr. Joe Silverman San Diego, CA 92152	1
Bureau of Navy Personnel	
Attn: Dr. Richard Elster, Pers OR	1
Attn: Mr. Robert Lehto, Pers 2X Washington, D. C. 20370	10
Operations Research Center University of California	
Attn: Dr. Richard Grinold	1
Attn: Dr. Robert Oliver Berkeley, CA 94720	1
Dr. Thomas Varley Office of Naval Research, Code 434 Arlington, VA 22217	1
LCDR Stephen Balut Center for Naval Analyses 1401 Wilson Boulevard Arlington, VA 22209	1
Dr. Roshan Chaddha Bell Telephone Laboratories Holmdel, NJ 07733	1
Mr. S. K. Khosla Personnel Department The World Vank 1818 H Street, N. W. Washongton, DC 20433	1
Defense Documentation Center (DDC) Cameron Station Alexandria, VA 22314	12
Library (Code 0212) Naval Postgraduate School Monterey, CA 93940	2
Library (Code 55) Naval Postgraduate School Monterey, CA 93940	2

Distribution List (cont'd)

	No. Copies
Dean Jack R. Borsting, Code 02	1
Professor Gordon H. Bradley, Code 55Bz	1
Professor Richard W. Butterworth, Code 55Bd	30
Professor Kneale T. Marshall, Code 55Mt	1
Professor Paul R. Milch, Code 55Mh	1
Dean David A. Schrady, Code 013	1
Professor John D. Senger, Code 54Se	1
Professor Michael G. Sovereign, Code 55Zo	1

Naval Postgraduate School
Monterey, CA. 93940